Noise reduction and energy savings of standard sound insulation packages for the control of road traffic noise

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ABSTRACT

Sound insulation of noise-sensitive buildings is a common means of mitigating road traffic noise. Methods for selecting appropriate sound insulation measures varies, with some Australian States requiring compliance with Australian Standard AS2107 or other internal noise criteria. An alternative used in some States is to specify standard packages of sound insulation measures based on external noise levels; noise-sensitive buildings (usually dwellings) exposed to higher external noise levels are required to have measures with higher noise reduction ratings incorporated into the building facade. VicRoads recently commissioned Marshall Day Acoustics and Earth Systems to undertake a study that broadly reviewed practises in some other Australian States; investigated the noise reduction achieved by a range of standard packages for both existing dwellings and, in the case of new residential estates near existing roads, new dwellings; and estimated the energy savings attributable to the standard packages.

INTRODUCTION

In certain circumstances where it is not practicable to provide adequate protection from freeway traffic noise, VicRoads provides architectural treatments to affected noise-sensitive buildings. These treatments typically include the provision of air conditioning to allow windows to be kept closed during warm weather. VicRoads was interested to understand whether the net impact on household energy consumption due to these architectural treatments would be positive or negative. Consequently Marshall Day Acoustics and Earth Systems were engaged to investigate both the acoustic and energy consumption impacts of a range of potential architectural treatments.

The study consisted of:

- A brief review of practices in some other States and countries
- Selection of standard acoustic treatment packages for new and existing dwellings
- Estimation of the noise reduction, cost, energy savings and greenhouse gas reduction for the selected packages.

SOME CURRENT PRACTICES

AS2107

Australian Standard 2107-2000 *Acoustics - Recommended design sound levels and reverberation times for building interiors* provides recommendations for acceptable internal noise levels. This Standard is commonly used to set criteria for road traffic noise.

Table 1 shows the recommended internal noise levels stated in AS2107 for 'houses and apartments near major roads.'

AS2107 does not specify the measurement procedure. It is Marshall Day Acoustics' practice to use the highest L_{Aeq} (short term, generally 15-60 minutes) during the night period (2200-0700hrs) for bedrooms and during the day and evening time periods of (0700-2200hrs) for other areas.

Table 1. AS2107 recommended noise levels, L_{Aeq} dB(A)

Area	'Satisfactory'	'Maximum'
Living areas	35	45
Sleeping areas	30	40
Work/utility areas	35	45
Apartment common areas (eg, lobbies)	45	55

AS3671

Australian Standard 3671-1989 *Acoustics – Road traffic noise intrusion – building siting and construction* provides guidance on the design and construction of buildings exposed to traffic noise in order to achieve internal sound levels in accordance with AS2107.

In the primary author's experience, the use of AS3671 is limited. This is likely to be because:

- In many cases, acoustic consultants are commissioned by developers. The consultant's advice will be directed toward compliance with AS2107, bypassing the need to refer to AS3671
- The process in AS3671 to select acoustic treatments requires calculations which may be too complex for non-specialists. Also, external noise levels must be measured or predicted, again requiring specialist input.

Association of Australian Acoustical Consultants

It is sometimes the case that residential developers wish to add value to their dwellings by achieving internal noise levels lower than the 'maximum' (actually the highest L_{Aeq}) recommended by AS2107. To assist developers to select more stringent criteria, an Acoustic Star Rating System has been developed by the Association of Australian Acoustical Consultants (AAAC, 2010).

'Deemed to comply'

A deemed-to-comply process is a simple process that allows builders to select acoustic treatments without the need for expert advice.

Such processes are likely to result in over-design in many cases, as several conservative assumptions will be necessary to ensure that acceptable internal levels will be achieved in the majority of cases. However, many builders and even some developers are likely to prefer a simple deemed-to-comply process, as it eliminates the need for specialist advice and/or compliance measurements.

'Deemed to comply' processes generally consist of:

- Identification of houses not requiring consideration due to their distance from the noise source or shielding by intervening buildings.
- Classification of the dwelling into one of a number of noise insulation categories based on the traffic volume and speed, and the distance from the dwelling to the road.
- Selection of standard acoustic treatments based on the classification.

Overseas Experience

Practice in the USA varies from state to state, with some States offering standard acoustic packages and other States requiring every dwelling to be assessed by a qualified person who then recommends insulation measures for each dwelling individually (Transport Research Board ADC40 Committee on Transportation-Related Noise and Vibration various members, personal communications, 2011).

While this latter approach may seem cumbersome, it can be the case that dwellings in a given area will be of similar construction, so that once one dwelling has been inspected in detail, subsequent dwellings can be inspected very quickly. Even with this approach, a range of standard packages can be prepared. The role of the qualified person undertaking the inspection then becomes to determine which packages suit which dwelling.

In Denmark, noise insulation grants are available that cover a portion of the cost of acoustic treatment to existing dwellings (J.Oddershede, Vejdirektoratet, personal communication, 6 September 2013).

The provision of sound insulation by government is well established in the United Kingdom. Under the British *Noise Insulation Regulations (1975)*, specific insulation measures are provided where roads are constructed or upgraded, resulting in noise levels in excess of 68 dB $L_{A10\ (18\ hour)}$. Similarly, sound insulation in the UK is provided where noise from railway traffic exceeds 68 dB $L_{A18\ (6am\ to\ midnight)}$ or 63 dB $_{LA6\ (midnight\ to\ 6am)}$ (Noise Insulation (Railway and Other Guided Transport Systems) Regulations 1996).

New South Wales

The State Environmental Planning Policy (Infrastructure) 2007 (the 'Infrastructure SEPP') came into effect in NSW on 1 January 2008. One of the objectives of the SEPP was to ensure that noise-sensitive developments adjacent to transport infrastructure were planned and constructed in a manner that addressed noise impacts.

The SEPP sets limits of 35dB(A) $L_{Aeq,9h}$ in bedrooms and 40dB(A) $L_{Aeq,15h}$ in other living spaces. This is approximately equal to an $L_{Aeq,1h}$ of 41dB(A) in bedrooms and 43dB(A) in other living spaces (Austroads 2005). This is slightly higher than the AS2107 range for sleeping areas (30-40dB(A)), but complies with AS2107 for living areas (35-45dB(A)).

There is a 'deemed to comply' procedure for detached houses. For multiple-unit dwellings such as townhouses and apartments, there is no 'deemed to comply' process, but there is a 'screen test' to identify dwellings that do not require acoustic treatment (Karantonis & Parnell, 2009).

With regard to existing dwellings, the Noise Abatement Program has been in place in NSW since 2001. However, standard insulation packages are not a component of this programme. Insulation requirements are determined on a case-by-case basis, within recommended budgets which are determined based on external noise levels. (NSW RTA, 2001)

Queensland

Section MP 4.4 – *Buildings in a Transport Noise Corridor* of the Queensland Development Code came into effect on 1 September 2010. This document relates to buildings constructed near major roads and railways.

Selection of acoustic treatment for new dwellings begins with prediction of external noise levels based on published traffic volumes. Depending on the external noise level, the proposed dwelling is placed in one of five categories (including one where no acoustic treatment is required). For each category, a 'transport noise reduction' from outdoor to indoor is required, and minimum R_w values specified for all building elements (doors, windows, etc). Specific building elements having the required R_w are then selected.

While the Code includes a 'deemed to comply' process for selecting acoustic treatment, there was no process for determining the necessary noise reduction other than by measuring or predicting external noise levels. This contrasts with NSW where there are simple charts provided.

The document does not address noise from new roads affecting existing dwellings.

South Australia

The Department for Transport, Energy and Infrastructure (DTEI) updated its *Road Traffic Noise Guidelines* in March 2007. The document sets out noise management principles and practices for existing dwellings affected by noise from new roads or major upgrades of existing roads. It sets out standard sound insulation packages to be considered in situations where external noise target cannot be practicably achieved.

The various packages are selected according to the amount by which the external noise level exceeds the external noise criteria.

There are aspects of a 'deemed to comply' approach in the DTEI guideline. There are no internal noise level objectives and compliance measurements are not required. However, external noise levels must be measured or predicted.

Note that subsequent to the current study, the South Australian Government issued Minister's Specification SA 78B Construction requirements for the control of external sound

(DPTI 2013). This document specifies particular construction requirements but does not specify interior noise levels.

Western Australia

State Planning Policy 5.4 *Road and Rail Transport Noise and Freight Considerations in Land Use Planning* provides a framework for management of noise from transport. Guidelines for implementation of the policy were released in May 2009. Section 4.5 of the guidelines sets out deemed-to-comply noise insulation packages.

Deviations from the deemed-to-comply packages are permitted, provided the design has been certified by a 'competent person'. Where external noise levels are above a certain threshold, an acoustic design by a competent person is required.

When compliance with the external noise limits cannot be achieved, internal criteria are specified:

> For residential buildings, acceptable indoor noise levels are $L_{Aeq(Day)}$ of 40dB(A) in living and work areas and $L_{Aeq(Night)}$ of 35dB(A) in bedrooms. For all other noise-sensitive buildings, acceptable indoor noise levels under this policy comprise noise levels that meet the recommended design sound levels in Table 1 of Australian Standard AS 2107:2000 Acoustics—Recommended design sound levels and reverberation times for building interiors.

Expressed in terms of the highest $L_{Aeq,1h}$, the specified acceptable indoor noise levels are approximately equivalent to 43dB(A) in living and work areas and may typically be as high as 42dB(A) in bedrooms (Austroads 2005).

Victoria

VicRoads currently requires compliance with AS2107 in new dwellings adjacent to freeways where it is not practicable to fully comply with the external noise target of 63dB(A) $L_{A10(18h)}$.

TYPICAL DWELLINGS

Three typical dwelling types were used for estimating the internal noise reduction of the sound insulation packages investigated. Table 2 provides some details of the dwelling types.

Table 2. Typical dwelling types

Dwelling type	Floor area (m^2)	Number of rooms (excluding wet areas)	Number of windows	Number of external doors
House	231	7	12	3
Apartment	84	3	3	1
Townhouse	141	3	5	3

The apartment was assumed to be on the top floor of a five-storey building. (The selection of five storeys was arbitrary; the significance is in the fact that the apartment was at the top floor.) The road generating the noise was assumed to be directly to the front of the property.

For the energy assessment, north was assumed to be directly to the front of the property. The base case (no acoustic treatment) existing dwellings were set up to achieve an energy star rating of about 1 star and had 3mm glazing. To be consistent with current building regulations in Victoria the base case new dwellings were set up to achieve a 6-star rating.

SELECTION OF NOISE INSULATION PACKAGES

Existing dwellings near new or upgraded roads

Of the interstate approaches reviewed, only the South Australian DTEI approach specified noise insulation packages for existing dwellings affected by new or upgraded roads. The SA packages were investigated. The SA packages are summarised in Table 3. The noise level excess is the excess above the target noise level. In fact, consideration is also given to the amount by which the noise level increases as a result of the new or upgraded road.

For the base case (no acoustic treatment), the typical dwellings were assumed to have the following attributes:

- The roof on the apartment was assumed to have low-performance insulation (such as R1.5) as provision of insulation in apartment ceiling space has been reasonably common practice for some time. For the house and townhouse, however it was assumed there was no insulation.
- Walls were assumed to be brick veneer.
- Vents on internal walls were assumed to be the 'indirect' type, generally consisting of a sub-floor vent in the outer brick skin and a vent in the inner plasterboard skin near the ceiling.

Table 3. Sound insulation packages for existing dwellings

Package	External noise level excess	Acoustic treatment
1	1-2dB(A)	• Provide acoustic seals to doors and windows • Treat air vents • Additional ventilation where necessary
2	3-5dB(A)	As for Package 1, plus: • Replacement of any external hollow core doors on the side of the building facing the road with solid core doors • Upgrading of glass doors and windows exposed to traffic noise to incorporate 10.38 mm thick laminated glass
3	5-8dB(A)	As for Package 2, plus: • Incorporate an additional pane of 6.36mm glass at 50mm spacing
4	>8dB(A)	As for Package 3, plus: • Install an additional layer of plasterboard such as 13 mm thick fire-rated plasterboard to the ceiling of the upper level of the building. Lay thick heavy density insulation (eg 100 mm rock wool) over the entire ceiling of the upper level of the building

New dwellings

The approaches for specifying noise insulation requirements for new dwellings in NSW, Queensland and WA were re-

viewed in detail. The Queensland approach was selected for further investigation. This is because:

- With four levels of acoustic treatment (categories), the programme represented a good compromise between simplicity and thoroughness.
- The glazing specified under the NSW programme did not appear likely to be sufficient to ensure compliance with AS2107.

Further investigation of the Queensland noise insulation packages found that:

- The AS2107 'maximum' limits were exceeded in the bedrooms with Category 4 noise insulation
- Compliance with AS2107 under Category 4 external noise levels was problematic:
  - Heavy double glazing was required in some bedrooms because the window sizes in the typical dwellings were typical rather than restricted in size.
  - Use of the same treatments throughout the house (the packages do not distinguish between room types, and orientation to the road is simplistic) lead to over-design in some rooms.

For this reason, it was decided to drop Category 4 and, if necessary, modify the remaining packages to ensure compliance with AS2107. The final packages assessed are shown in Table 4.

The acoustic treatments shown in Table 4 generally achieved internal noise levels that were:

- At or below the 'recommended' level specified by AS2107 under Category 0 (base case).
- Close to the middle of the AS2107 noise level range for Category 1 and 2 treatments.
- At or below the 'maximum' level specified by AS2107 under Category 3.

Table 4. Sound insulation packages for new dwellings

External noise level, $L_{A10(18h)}$	Package	Acoustic treatment
$\leq$ 57	0	• None
58-62	1	• Acoustic seals on doors and windows
63-67	2	• 10.38mm laminated glazing • 2 layers of plasterboard on the ceiling • Acoustic seals on doors and windows
68-72	3	• 16mm plywood sarking (house) • 10mm plasterboard sarking (town house and apartment) • 2 layers of plasterboard on the ceiling • 6/50/10 double glazing on windows • Sliding doors replaced with 40mm solid core timber doors • Acoustic seals on doors and windows
$\geq$ 73	4	• Site-specific design by a qualified person

All new dwellings in Victoria must be at least six-star rated for energy efficiency. For the base case (no acoustic treatment), the typical dwellings were assumed to have the following attributes:

- All glazing (windows and sliding doors) was 6mm monolithic, except for in bathrooms and laundries, where the glazing was 3mm monolithic.
- The roof on the apartment and town house was corrugated iron or metal deck. The roof on the house was tiled.
- R4.0 glasswool batts in the roof plus 1 layer of anti-glare foil.
- R2.0 glasswool batts in external walls.
- Conventional seals on all external doors and windows
- Walls were assumed to be brick veneer.
- All vents and exhaust fans are run either into the ceiling space or are enclosed with a flap that remains closed when the fan is not operating.
- All external doors (other than sliding doors) were 40mm solid-core doors.

ACOUSTIC ASSESSMENT METHOD

Noise reduction estimates

For each dwelling type, internal noise levels were calculated for the base case (no acoustic treatment) and for the dwellings fitted with the noise insulation packages.

The difference in internal noise levels between the scenarios with the acoustic treatment and the base case scenario was then determined.

External noise level

The performance of the various treatment packages is independent of the external noise level, but not of the external noise spectrum. A brief review of traffic noise measurements with and without trams concluded that despite common perceptions that trams generate high levels of low frequency noise, it was clear that when expressed in L_{Aeq}, there was no significant difference. The standard spectrum for road traffic noise given in International Standard ISO 717 *Acoustics - Rating of sound insulation in buildings and of building elements* was selected.

RESULTS

Existing dwellings

Noise reductions relative to the base case were determined for the SA DTEI packages for the typical dwellings.

Table 5 compares the average noise reductions for all dwelling types.

Table 5. Noise reductions (dB(A)) - existing dwellings

Package	Houses	Apartments	Townhouses	External noise level excess
1	3	2	2	1-2
2	5	4	5	3-5
3	5	4	5	5-8
4	12	12	11	>8

The values shown are the average of the noise reductions for all bedrooms and living areas for each dwelling type.

Package 1 provided 2-3dB(A) of noise reduction, 1-2dB(A) of which was due to treatment of the vents. Provision of solid core doors and new, heavier windows under Packages 2 and 3 resulted in small reductions, but this was limited by the poor acoustic performance of the acoustically uninsulated ceiling. Adding ceiling insulation and a second layer of plasterboard under package 4 not only improved the acoustic performance of the roof/ceiling, but allowed the improved window and door performance to become apparent.

In all cases, the internal noise reduction was consistent with the amount by which the external noise level exceeded the external noise objective.

Sensitivity to base case assumptions

For the base-case dwellings, it was assumed that there was no bulk insulation in the ceiling space. There are many existing dwellings that do have ceiling insulation. Had we assumed there was basic bulk thermal insulation in the ceiling, the noise reductions achieved by Packages 2 and 3 would have been greater. The Package 4 noise reductions would have been unaffected, assuming the existing insulation was removed and replaced with the specified acoustic insulation.

Provision of ventilation made no difference to the noise reduction estimates. This is because it was assumed that:

- The windows would be closed whether or not there was alternative ventilation.
- The ventilation system did not introduce a new sound path for traffic noise to enter into the dwelling, if necessary by acoustic treatment.

If, prior to installing the alternative ventilation, it was necessary to keep the windows open to adequately ventilate the dwelling, then providing alternative ventilation would achieve a noise reduction of approximately 10dB(A) as, in most conventional dwellings, closing the windows will generally reduce noise from outside the dwelling (as measured inside) by 10dB(A).

New dwellings

Noise reductions relative to the base case were determined for the packages shown in Table 4 for the different dwelling types.

Table 6 compares the average noise reductions for the typical dwellings.

Table 6. Noise reductions (dB(A)) - new dwellings

Package	Houses	Apartments	Townhouses
1	1	1	1
2	3	5	4
3	8	9	8

With new dwellings, the base case dwellings already had a fair level of sound insulation. To maintain good compliance with AS2107, the only treatment under Package 1 was improvement of the door and window seals, which only improved the overall performance by 1dB(A).

Provision of two layers of plasterboard throughout the house was not necessary to comply with AS2107, so Package 2 represented a significant over-design. However, the two layers were required in some rooms in the apartment and townhouse. This demonstrates one of the drawbacks of a package-based approach – that in order to cater for all situations, a degree of overdesign can occur in some cases.

COST ESTIMATES

Method

The costs of providing and installing the acoustic packages was determined using Rawlinsons *Australian Construction Handbook* (Rawlinsons, 2010). The costs include labour and overheads as though the project was a major construction project (value over $1.5M). Thus, the cost estimates are likely to be reasonably accurate for new apartments or new rows of townhouses, but for the other dwelling types, the estimates will be low, as there is no allowance for:

- Additional (relative) overheads and inefficiencies encountered in smaller construction projects.
- Additional labour and waste removal when retrofitting existing dwellings.

Other aspects of the cost estimation worth noting are:

- The cost of alternative ventilation under Package 1 for existing dwellings was based on ducted refrigerated air-conditioning.
- The cost of plywood or plasterboard sarking under Package 3 for new dwellings was assumed to be equal to the cost of a second layer of ceiling plasterboard
- The cost of making up and fitting an additional pane of 6.38mm laminated glass under Package 3 for existing dwellings was assumed to be the same as the cost of making up and fitting a window with 6.38mm glazing
- The cost of acoustic treatment of vents was not provided in Rawlinsons. The cost was estimated as the cost of replacing the vent with an extraction fan.

Results

Table 7 shows the cost estimates for existing dwellings.

Table 7. Cost estimates for existing dwellings

	Package	House	Apartment	Townhouse
1	No air-con	$2,000	$1,000	$3,000
	With air-con	$24,000	$9,000	$16,000
2	No air-con	$20,000	$9,000	$15,000
	With air-con	$41,000	$16,000	$29,000
3	No air-con	$18,000	$8,000	$14,000
	With air-con	$39,000	$16,000	$28,000
4	No air-con	$35,000	$14,000	$25,000
	With air-con	$56,000	$22,000	$39,000

Note. All costs rounded to the nearest $1,000.

In all cases, the most expensive item was the air-conditioning. Other major cost items were the glazing and second layer of plasterboard.

Package 3 costs less than Package 2 because the cost of the additional pane of 6.38mm laminated glass under Package 3 was less than the cost of a new window incorporating 10.38mm thick laminated glass. This may not always be the case, depending on the design of the existing window frame and sill.

Table 8 shows the cost estimates for new dwellings.

Table 8. Cost estimates for new dwellings

Package	House	Apartment	Townhouse
1	$2,000	$1,000	$2,000
2	$31,000	$13,000	$22,000

3	$42,000	$15,000	$28,000

Major cost items were the glazing, the second layer of plasterboard and the sarking.

ENERGY SAVINGS

Earth Systems Pty Ltd was commissioned to estimate the energy savings associated with the acoustic treatment packages. These calculations are generally used as a measure of the heating and cooling thermal performance of residential buildings. In order to simplify the thermal modelling, it was necessary to assume that the base case buildings had the same heating and cooling equipment as the upgraded buildings. Thus, the additional energy cost associated with installing mechanical ventilation was not evaluated.

Table 9 compares the energy consumption for existing dwellings.

Table 9. Energy consumption (MJ pa) – existing dwellings

Package	Houses	Apartments	Townhouses
Base	102,400	45,200	63,200
1	96,600	42,100	58,200
2	96,400	41,800	58,100
3	94,700	41,200	57,500
4	32,800	8,000	34,300

The upgrade to the glazing and seals provided modest reductions in energy consumption under packages 1-3. By far the greatest reduction (70%-80%) was achieved by the addition of insulation to the ceiling space under package 4.

Table 10 compares the energy consumption for new dwellings.

Table 10. Energy consumption (MJ pa) – new dwellings

Package	Houses	Apartments	Townhouses
Base	23,300	8,600	14,700
1	22,200	8,000	14,200
2	22,100	7,900	14,200
3	17,400	6,700	11,000

For the new dwelling the reductions in energy consumption are not so significant as for the existing dwellings, as the base case dwellings were already relatively energy efficient at 6 stars. Packages 1 and 2 achieved reductions of 4%-8%, with package 3 achieving 22%-26% reductions relative to the base case.

ISSUES

Issues that may affect a noise insulation programme based on fixed packages are:

- Application of fixed packages may result in extra cost. Acoustic treatments based on fixed packages will generally be more costly, particularly if a 'deemed to comply' process is used to select the package rather than noise measurements or detailed modelling. This should be made clear in any regulations, and builders/developers given the option of designing to and confirming compliance with internal criteria.
- Existing dwellings eligible for treatment may already incorporate elements of the relevant package. For example, there is little point in offering door seals and ventilation to someone whose home already has door seals and ventilation. The SA DTEI guideline states that 'packages should only be offered where they are expected to result in a significant reduction in noise levels.' This is a reasonable approach, but would require an initial inspection to determine (amongst other things) whether eligible dwellings already have some elements of the packages.
- Packages incorporating specific treatments may not address the major sound paths and so may make little or no difference to internal sound levels. For example, there is little point in installing door seals and ventilation in a house with louvre windows. Packages may need to be modified so that, for example, 6.38mm glazing is provided in combination with the standard items.
- One significant source of over-design can be specification of packages that are applied to the entire house. In some cases, treatments necessary to achieve compliance in the worst-affected rooms are not necessary in some other rooms.
- The rooms to which packages are applied to should be specified. The SA DTEI guideline states that 'corridors, passageways, bathrooms and laundries should not be treated.'
- Trigger noise levels for selecting packages need to be considered. The SA DTEI guideline looks not only at how much the predicted noise levels exceed the external criteria, but how much the noise levels exceed the pre-construction noise levels.
- Building inspectors need to be trained. The packages investigated in this report are very simple and should require little in the way of training. If greater flexibility was incorporated to allow builders to select alternative treatments, or for different treatments to be selected depending on exposure to the noise source, then more detailed training may be required.
- Process for selecting building elements. The NSW Infrastructure SEPP specifies R_w values for all building elements. Builders can select alternative elements provided they have the same R_w. However, many house builders are not familiar with the R_w concept and, in our experience, tend to choose alternatives based on popular misconceptions.
- The quality of installations must be controlled. One colleague reported that a US Federal Aviation Administration programme supplying 'standard' noise abatement packages to dwellings affected by aircraft noise was not universally well received, primarily due to poor quality workmanship by low bid contractors. Adequate training of inspectors should help to address this problem.
- In some US States, owners are given the option of paying the difference between the package they are entitled to under the scheme and any of the more effective packages. However, the fact that the estimated cost of the SA DTEI package 3 was less than package 2, there may need to be some refinement of the packages before such a scheme would make sense.

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